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Response Rate Controlled by Two Liquid Reinforcers in a Multiple Schedule

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by Two Liquid Reinforcers

In a Multiple Schedule

by

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A large body of research has been devoted to the study of reinforcers and the behavioral control they exert under different reinforcement schedules. A reinforcer is "any event, when used in the temporal relations specified in reinforcement, is found to produce the process of conditioning" (Ferster & Skinner, 1957). By definition, the presentation of a reinforcer increases the probability that a particular behavior will be repeated.

A schedule arranges the conditions present at the occurrence of a reinforced response. The schedule may specify the delivery of a reinforcer after each response (continuous reinforcement) or following a number of unreinforced responses (intermittent reinforcement). Some schedules of intermittent reinforcement are Fixed Ratio (FR), Fixed Interval (FI), Variable Ratio (VR), and Variable Interval (VI) (Ferster & Skinner, 1957). In these schedules, two important factors coincidental with the occurrence of a reinforcer are time and number of responses. These dimensions can be held constant or varied.

In an FI schedule, for example, "the first response occurring after a given interval of time measured from the preceding reinforcement is reinforced" (Ferster & Skinner, 1957). In terms of sequence, the FI begins at the end of the timing of the previous FI (Cumming & Schoenfeld, 1958). Under the contingencies of an FI schedule, a characteristic pattern of responding known as the scallop develops over time. The scallop is an upward concavity of the cumulative record of successive intervals showing an increase in response rate as the time interval nears completion. The scallop is preceded by a temporary cessation in responding (pause) following the delivery of each reinforcer. The duration of pause varies with the temporal specifications of the FI. The number of responses in each interval varies, but the average number over extended sessions remains constant provided the duration of the FI and conditions of the organism are kept constant (Dews, 1970).

The precise properties of the behavior controlled by intermittent schedules are dependent upon a number of variables. These include size of the ratio or interval, response topography, or some property of the reinforcer. Any of the various conditions underlying intermittent reinforcement may be manipulated to determine its relationship to the existing behavior.

The "quantity" and "quality" of reinforcers are important parameters influencing operant behavior. Quantity is specifiable in terms of some physical measure such as volume or number. The quality of a reinforcer, however, has usually been determined in studies using choice or "preference" designs (Kimble, 1968). Frequently, the quality of a reinforcer has been manipulated by varying the concentration of a soluble substance in water. Advantages of using liquid reinforcers include a reduction in required ingestive activity (Stebbins, Mead, & Martin, 1959) and the convenience of precisely measuring the concentration (Young, 1966). Liquid reinforcers also enable the manipulation of the quality of a reinforcer while controlling for variations in quantity such as volume.

The effectiveness of a liquid reinforcer in terms of operant behavior varies as a function of concentration (Collier & Siskel, 1959; Guttman, 1953, 1954; Hodos, 1961; Shrier, 1965; Stebbins, et al., 1959). Typically, response rates vary with deprivation level and quality of the reinforcer (Collier & Willis, 1961). Guttman (1953) assessed response rates in rats by systematically varying sucrose concentrations as reinforcers from 0% to 32%. Response rates under FI and VI schedules varied directly as a function of the percentage of sucrose in the reinforcer.

Hodos (1961) varied concentrations of sweetened condensed milk used as a reinforcer under a progressive FR schedule. In using this type of schedule, the required number of responses necessary for a reinforcer to occur was progressively raised by a fixed increment of two. Each run of responses in the progressive FR was called a ratio run. The number of responses in the last complete ratio run before a 15 minute pause occurred was used as an index of the strength of the reinforcer. Using this procedure, it was found that as the sweetened condensed milk concentration declined, the final number of responses in the progressive FR declined. The highest concentration of sweetened condensed milk used (50%) was found to be the most effective in maintaining responding.

Several studies have used multiple schedules of reinforcement to determine the behavioral control exerted by different quantities of reward (Catania, 1963; Keesey & Kling, 1961; Shettleworth & Nevin, 1965). In multiple schedules (Ferster & Skinner, 1957) the schedule requirement specifies the performance of several different behaviors, each occasioned by a particular extroceptive stimulus (presented in sequence in a regular or random series). Ferster and Skinner (1957) list several specifications of a multiple schedule. These involve variations in component schedules, response topography, extroceptive stimuli, or form of reinforcer. The existence of two or more extroceptive stimuli and two or more component schedules are standard criteria in all multiple schedules (Sidman, 1960). In each case, the availability of a primary reinforcer is delivered in accordance with the schedule in effect.

A schedule composed of two or more extroceptive stimuli usually involves the process of discrimination. The extent to which a specified stimulus determines the probability of the occurrence of a conditioned response refers to the amount of stimulus control over the behavior (Terrace, 1966a). When stimulus control is achieved, an organism reacts to a particular stimulus in accordance with the consequences of that stimulus in relation to the schedule in effect. One component schedule may be an FI and the other extinction. "Correct" responses are reinforced and "incorrect" responses are extinguished. Standard techniques usually assess the percentage of response distribution between alternate responses (Ferster & Skinner, 1957). The characteristics of simple FI responding are also found when used as components of a multiple schedule.

Multiple schedules have several advantages associated with their use in certain kinds of behavioral research. A multiple schedule enables the sampling of a variety of behaviors in a single organism in short periods of time. In addition to the large amount of data obtained in each experimental session (Hernstein & Brady, 1958), a reduction in within subject variability is often noted when compared with discrete observations under different conditions (Dinsmoor, 1966).

The use of a multiple schedule also enables the comparison of two or more reinforcers with different quality at the same time. The present study compares response rates controlled by various concentrations of sweetened condensed milk and honey used as reinforcers in a multiple FI 1 FI 1 schedule of reinforcement. An FI 1 (one minute) component schedule was chosen as a precaution to minimize satiation effects noted in some previous studies where higher concentrations of other reinforcers such as sucrose solution were investigated (Marx & Pieper, 1963). A 50% concentration of sweetened condensed milk was selected as a standard for comparison based on prior research by Hodos (1961). Although a 50% concentration of sweetened condensed milk has been shown by Hodos (1961) to be an effective reinforcer, the reinforcing effectiveness of varying concentrations of honey have not been determined using a procedure where choice is not utilized.

Method

Subjects

Eighteen male albino rats approximately 90 days old obtained from Cherokee Laboratory Supply Company were used. All animals were immediately placed on free feeding with Purina Lab Chow for fourteen days. After this period, the rats were reduced and maintained at 80% of their former free feeding weights. Throughout the experiment, the animals lived in separate cages where they had free access to water.

Apparatus

The apparatus consisted of a closed experimental chamber measuring 31.0 cm. x 21.5 cm. x 19.5 cm. Two levers 30 cm. apart were positioned 4 cm. above the grid floor. Each lever, operating at a force of .16 Newtons, was associated with a white cue light (1.5 cm. in diameter) and dipper mechanism. Operation of either dipper delivered .25 ml. of liquid reinforcer. The experimental chamber was situated in a sound attenuating cell. Standard electromechanical equipment located in an adjacent room was used to program the contingencies and record responses.

Procedure

All rats were trained to bar press and discriminate through standard shaping procedures until reliable and accurate responding on both levers was obtained under an FI 1 schedule of reinforcement. The schedule was then changed to a multiple (mult.) FI 1 FI 1 for the remainder of the experiment. A description of the contingencies based on the notation system by Mechner (1959) is given in Figure 1. Each lever was operative for five component FI 1 schedules in succession, with the completion of each component FI 1 followed by a reinforcer. Only one lever was operative for each five FI 1 sequence. Responses made to the inoperative lever were followed by no programmed contingencies (extinction). A session terminated after an animal had received 30 reinforcers or 35 minutes in the experimental chamber.

To establish baseline, a 50% "Sue Bee" honey and distilled water solution (by weight) mixed with a 50% "Borden's Eagle Brand" sweetened condensed milk and distilled water solution (by weight) was used as a reinforcer. This was a combination of the reinforcers to be used in the subsequent phase of the experiment. The criterion for response stability during baseline was ten sessions with response rates varying not more than plus or minus 10% and no consistent trend in the data.

Baseline criterion was reached in 34 sessions. The animals were then matched in terms of mean responses per FI for the last ten sessions of baseline and assigned to six

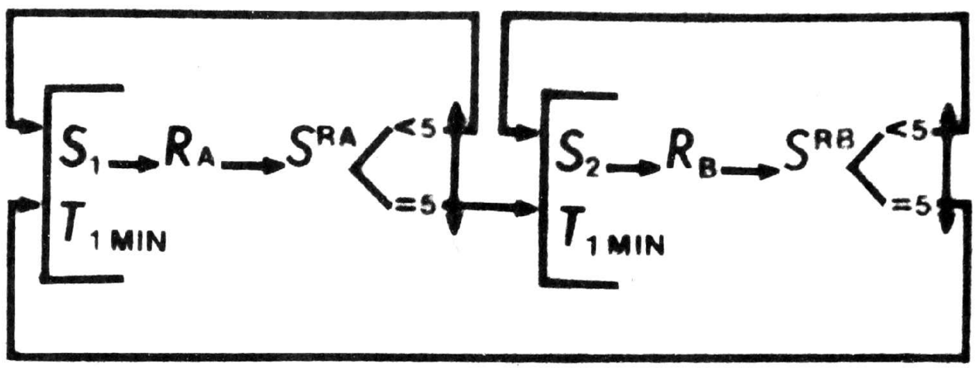

Fig. 1. The mult. FI 1 FI 1 schedule sequence used. Each lever was operative for five component FI 1 schedules in succession.

groups of three animals each. The groups were run under the following specifications. Responses to lever A (when operative) were reinforced with a 50% sweetened condensed milk and distilled water solution. Correct responses to lever B (responses to lever B while operative) were reinforced with specific concentrations of honey and distilled water solution. Each group received a different concentration of honey for correct responses to lever B, with concentrations ranging from 0% (distilled water) to 50% in 10% increments. The specific concentrations of solutions presented to each group are given in Table 1. This procedure was maintained for 23 sessions, with the former criterion for response stability being achieved for all groups.

TABLE 1

Various Concentrations of Reinforcers Presented

Group	lever A	lever B
1	50% Milk	0% Honey
2	50% Milk	10% Honey
3	50% Milk	20% Honey
4	50% Milk	30% Honey
5	50% Milk	40% Honey
6	50% Milk	50% Honey

Results

Figure 2 gives the results in terms of mean correct responses per FI for each of the six groups. Each group was designated by the concentration of honey received for correct responses to lever B. Values were computed for both levers based on the last ten sessions of the experiment. The resulting response curve for honey was found to vary almost directly as a function of increasing concentration. An exception to this generalization occurred at 20% honey where the mean correct responses per FI slightly exceeded those for 30%.

The mean total correct responses per FI to lever A (resulting in the presentation of milk as a reinforcer) was found to decrease as a function of honey concentration associated with lever B, with responses per FI on lever A and lever B almost equal in the group receiving 40% honey for correct responses made to lever B. A repeated measures analysis of variance (Table 2) indicated significant differences at the .01 level of confidence. Through the use of a Newman Keuls post hoc comparison test (Kirk, 1968), group mean responses per FI were found to be significantly different at the .01 level of confidence for the 0% honey

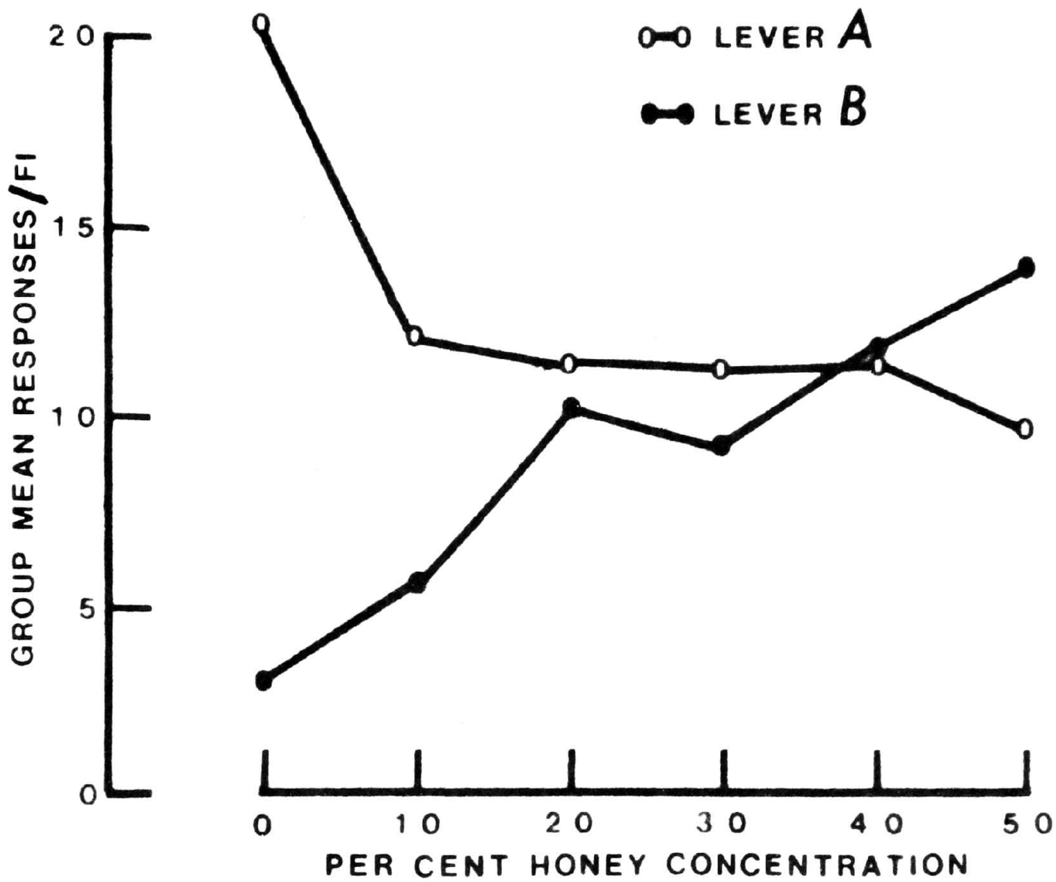

Fig. 2. Average number of responses which occurred in each FI to lever A (milk) and to lever B (honey). The means were calculated based on the last ten sessions of the experiment.

TABLE 2

Results of Analysis of Variance

Source	df	Ms	F
Between Gps.			
A	5	9.24	.67
S (A)	12	16.80	
Within Gps.			
B	1	120.82	9.25 *
A X B	5	88.47	6.77 **
B X S (A)	12	13.05	

$F_{.95}\ (1,12) = 4.75$

$F_{.99}\ (5,12) = 5.06$

group and at the .05 level of confidence for the 10% and 50% honey groups.

Figure 3 shows each group's performance curve in terms of per cent total correct responses relative to baseline. The results were found to be in general agreement with curves based on mean correct responses per FI over the last ten sessions of the experiment.

Accuracy in discrimination was also affected by the various concentrations of honey presented as reinforcers. Figure 4 indicates that, although discrimination for honey was found to be relatively stable and accurate across groups, discrimination for the 50% sweetened condensed milk was related to the concentration of honey in the opposing schedule sequence. This was due to responses made to the inoperative milk lever while the opposing schedule sequence for honey was in effect. Overall stimulus control was found to be greatest in the 40% and 50% honey groups.

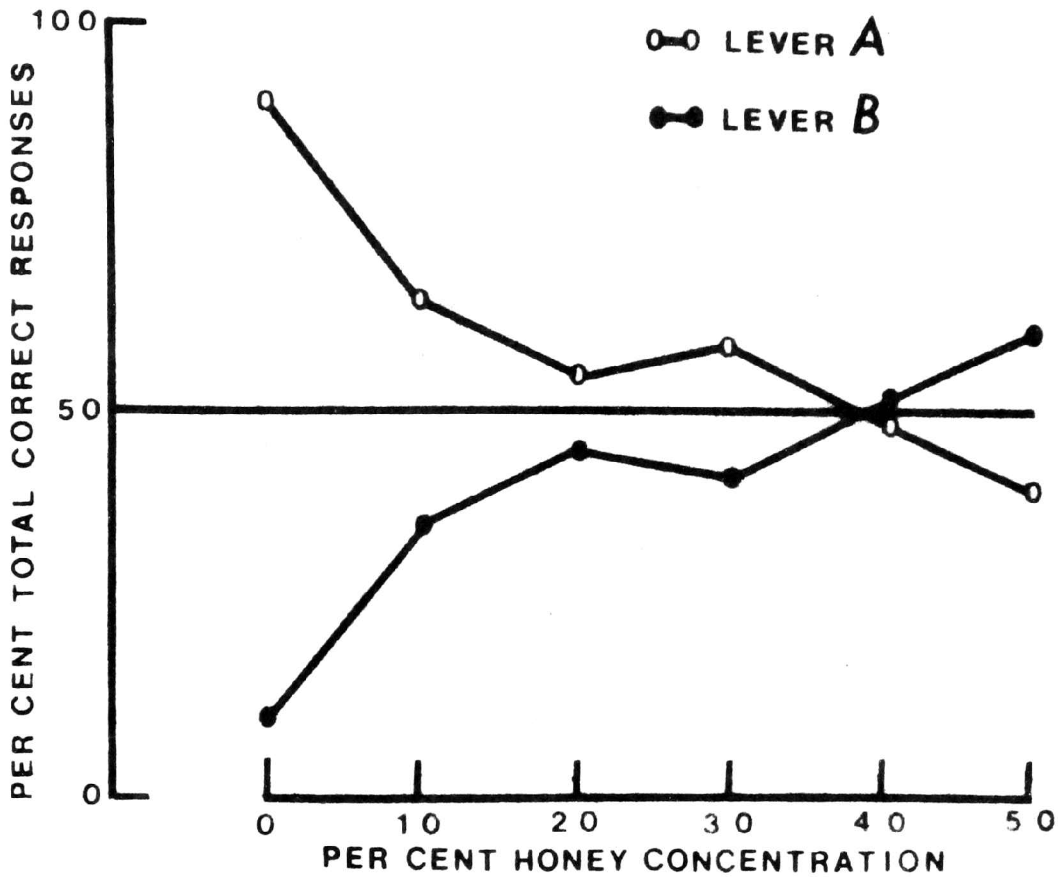

Fig. 3. Per cent of correct responses to lever A (milk) and lever B (honey) adjusted for initial baseline preference. Values for lever B were based on mean correct responses to lever B divided by mean correct responses to both levers converted to per cent. The corresponding values for lever A were obtained by subtracting the percentage value for lever B from 100 per cent.

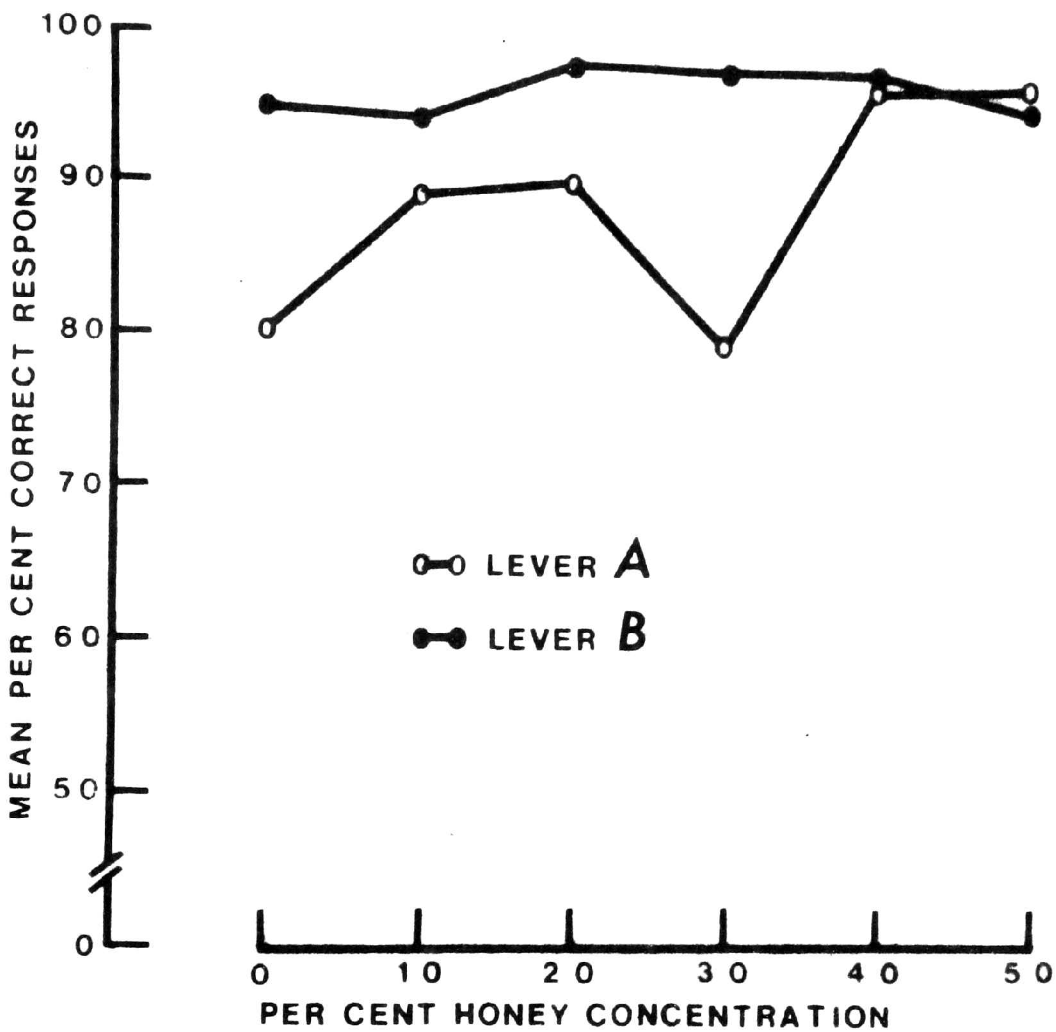

Fig. 4. Mean per cent correct responses per group to lever A (milk) and lever B (honey) over the last ten sessions of the experiment. Values were calculated for each lever based on the number of correct responses to that lever divided by the total number of responses to that lever.

Discussion

The present study found that responses per FI to the honey lever were generally higher with increasing concentration of the honey reinforcer. A large number of studies have shown that response rate is influenced by reinforcer quality and quantity (Pubols, 1960). Generally, the response curves found in the present study with honey are in agreement with Guttman's (1953) research with varying concentrations of sucrose used as a reinforcer under simple FI contingencies.

The results shown in Figure 2, however, indicate a slight variability from Guttman's (1953) response curve in the 20% honey group. This variability was not unusual (Pubols, 1960). A variety of factors have been shown to influence the results of studies investigating the parameters of reinforcement (Kling & Riggs, 1971). Differences in procedure and overall design features generally have not facilitated valid comparisons between studies. Early research in amount of reward using mazes (Pubols, 1960) provided limited control over extraneous stimulation (Kling & Riggs, 1971). This, in addition to excess handling of the animals due to discrete trials, resulted in large variations in individual response measures.

Although operant techniques have allowed more control over the experimental situation, difficulties in assessing results still appear. A major difficulty is that responding is strongly influenced by the type of schedule and session length. Studies with rats done by Collier and Siskel (1959), Collier and Myers (1961), Collier and Willis (1961), and Collier (1962) have indicated that response rates decline over the course of a session. The rate of this decline is greater at higher concentrations, larger volumes, and higher densities of reinforcement (when interreinforcement time is of short duration, as is the case with continuous reinforcement). These variables may interact to influence the results of experiments concerned with investigating the effects of amount of reinforcer.

Guttman (1953), for example, has reported nonmonoticity of responding as a function of reinforcer concentration under conditions of continuous reinforcement (CRF), whereas an FI 1 schedule was found to generate a somewhat linear curve. The use of intermittent reinforcement such as an FI 1 schedule seems to aid in minimizing the effects of satiation sometimes found when higher concentrations of reinforcers are investigated over extended sessions (Marx & Pieper, 1963). In that an FI 1 schedule was used as a component schedule in the present study (in conjunction with relatively short sessions) the probability of satiation effects should have been reduced, although no attempt to investigate this possibility was specifically attempted.

With regard to the 50% sweetened condensed milk standard used in the present study, responses per FI were found to be comparable to responses for honey concentrations in the vicinity of 40% (see Figure 4). A 50% honey concentration used as a reinforcer was found to generate a significantly greater number of responses per FI than a 50% concentration of sweetened condensed milk. In the zero, ten, and 50% honey groups, the mean responses per FI were clearly different. It must be noted that the data represent values obtained following a "shift" from the baseline condition to the various reinforcer concentrations. Some prior research has indicated that this enhances the development of "behavioral contrast effects" (Kling & Riggs, 1971). According to Catania (1968), contrast is said to involve a change in the rate of one response accompanied by a change in the opposite direction of the rate of a second response. Reynolds (1961) noted behavioral contrast using a mult. VI-extinction schedule with pigeons. It was found that response rates were higher when a VI schedule was used as a component of a mult. schedule than when it was the only schedule. This effect was described as positive behavioral contrast. The increasing rate of the VI component of the multiple was said to result from a lowered frequency of reinforcement on the other component of the multiple rather than a lowered rate of responding on that component. Similarly, negative behavioral contrast may be produced when the frequency of reinforcement is increased in one component of a multiple schedule (Kling & Riggs, 1971).

There is some evidence that behavioral contrast decays over a large number of test sessions. Terrace (1966b), using a shift procedure, reported a decline in contrast over 60 sessions using a mult. VI-extinction schedule. However, Bloomfield (1967), also using a similar mult. VI-extinction schedule, found no signs of decay over the same number of test sessions. The present study, by comparison, involved a smaller number of sessions than Terrace (1966b) with a mult. FI 1 FI 1 schedule under different reinforcer concentrations. However, all animals were observed to achieve relatively stable rates of responding during the last ten sessions with no signs of major shifts in response distributions.

Finally, an overall increase in stimulus control was found as the concentrations of the reinforcers on the opposing levers became more comparable (in terms of responses per FI). The results shown in Figures 2 and 3 are related in that with the groups receiving less than 40% honey, discrimination was less accurate to the 50% milk lever. In these groups, inaccurate responding to the 50% milk lever frequently replaced responding to the opposing honey lever while the schedule sequence for honey was in effect. This indicates that when reinforcer strength varies greatly between operanda on a mult. FI 1 FI 1 schedule the accuracy in responding decreases.

Summary

The effects of varying concentrations of honey relative to a 50% concentration of sweetened condensed milk under a mult. FI 1 FI 1 schedule of reinforcement were investigated. Responses per FI on the honey lever were generally found to increase with increasing concentrations of honey presented as a reinforcer. As honey concentration increased in one component of the multiple, a systematic decrease in responses per FI was noted in the schedule component presenting sweetened condensed milk as a reinforcer. Significant differences in responding at the .05 and .01 levels of confidence were noted.

Accuracy in discrimination under the mult. FI 1 FI 1 schedule was also affected by the various concentrations of honey presented as reinforcers. Accuracy in discrimination for the 50% concentration of sweetened condensed milk was related to the concentration of honey in the opposing schedule sequence. Accuracy was poorest when the concentration of honey reinforcer was low.

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APPENDIX

DATA SUMMARY, HONEY CONDITION

Group	Rat	(2 in 2)	(1 in 1)	$\frac{2 \text{ in } 2}{1 \text{ in } 1+2 \text{ in } 2}$	Group Ratio
	G	2.99	16.05	.16	
1	H	3.74	27.24	.12	.14
	I	2.59	17.81	.13	
	J	5.20	5.83	.47	
2	Q	5.43	21.47	.20	.35
	N	6.06	9.26	.39	
	L	7.98	10.62	.42	
3	M	16.69	10.29	.61	.44
	S	6.40	14.05	.31	
	A	11.84	14.48	.45	
4	B	6.52	9.26	.41	.44
	D	9.64	10.71	.47	
	P	10.72	8.92	.54	
5	O	14.21	15.96	.47	.50
	R	10.43	10.14	.50	
	C	14.88	11.76	.56	
6	E	16.16	10.21	.61	.61
	F	13.79	7.16	.66	

DATA SUMMARY (cont'd)

Group	Rat	Corrected Ratio	Milk Ratio	Mean Resp/FI Lever 2	Lever 1	Disc. 2	Disc. 1
1	G H I	.10	.90	3.11	20.37	.95	.81
2	J Q N	.35	.65	5.56	12.18	.94	.89
3	L M S	.45	.55	10.35	11.65	.98	.90
4	A B D	.42	.58	9.33	11.48	.97	.79
5	P O R	.51	.49	11.78	11.67	.97	.97
6	C E F	.60	.40	14.94	9.71	.94	.97